CLAIMS

1. An optical waveguide modulator equipped with an output light monitor comprising:

an optical waveguide element comprising a dielectric substrate and an optical waveguide formed on a front surface of the dielectric substrate, the optical waveguide comprising a plurality of surface optical waveguide portions, an optical waveguide connecting portion on which the surface optical waveguide portions are converged and connected to each other and an output light-outputting optical waveguide portion connected to the optical waveguide-connecting portion;

an optical fiber for output light, connected to an output end of the output light-outputting optical waveguide portion of the optical waveguide element;

a reinforcing capillary for reinforcing a connection between the optical waveguide element and the output light-outputting optical fiber; and

a means for receiving monitoring light, wherein

the reinforcing capillary is provided with a hole or groove formed therein for containing and holding the optical fiber for output light, a connection surface thereof connected to an output end side surface of the substrate of the optical waveguide element, and a terminal surface thereof opposite to the connection surface, to thereby enable the reinforcing capillary to receive the monitoring light outputted from the optical waveguide element through at least one member selected from the capillary itself and the optical fiber for the monitoring light located in the capillary, to transmit the monitoring light therethrough and to output the monitoring light to the outside of the capillary; and

the monitoring light-receiving means is located in a position in which the monitoring light outputted from the reinforcing capillary to the outside

of the capillary can be received, and is provided with a photoelectric conversion element.

2. The optical waveguide modulator equipped with an output light monitor as claimed in claim 1, wherein the reinforcing capillary is formed from a light-transmittable material, to thereby enable radiation mode light generated in the optical waveguide connecting portion of the optical waveguide element to pass through the dielectric substrate and to be received by the light-transmittable reinforcing capillary, and the radiation mode light outputted from the reinforcing capillary to be received, as monitoring light, by the monitoring light-receiving means.

3. The optical waveguide modulator equipped with an output light monitor as claimed in claim 2, wherein the light-transmittable material for the reinforcing capillary is selected from transparent glasses.

4. The optical waveguide modulator equipped with an output light monitor as claimed in claim 2, wherein the terminal surface of the reinforcing capillary formed from the light-transmittable material is a light-reflective surface, to thereby enable the radiation mode light radiated from the optical waveguide connecting portion of the optical waveguide element to pass through the dielectric substrate of the optical waveguide element and the reinforcing capillary connected to the output end surface of the dielectric substrate, and to be reflected on the terminal light-reflective surface, and the reflected radiation mode light to be received, as a monitoring light, by the monitoring light-receiving means.

5. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein the reinforcing capillary is in the form of a cylinder.

6. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein the reinforcing capillary is a transparent glass

cylinder; a hole or groove for holding the optical fiber for the output light is formed along the longitudinal axis of the transparent glass cylindrical capillary; and the longitudinal axis of the hole or groove intersects the light-reflective terminal surface at an oblique angle.

7. The optical waveguide modulator equipped with an output light monitor as claimed in claim 6, wherein the radiation mode light reflected on the reflective terminal surface of the cylindrical reinforcing capillary is transmitted toward a periphery of the capillary and then is outputted, as a monitoring light through the periphery of the capillary, the outputted monitoring light is converged by a lens effect of the periphery of the cylindrical reinforcing capillary, and the converged monitoring light is received by the monitoring light-receiving means.

8. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein a light-reflective membrane is formed on the terminal surface of the reinforcing capillary.

9. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein the terminal surface of the reinforcing capillary is formed into a curved surface projecting outward to thereby enable the monitoring light transmitted through the reinforcing capillary to be reflected and converged on the curved terminal surface, and then to be received by the monitoring light-receiving means.

10. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein the connection surface of the reinforcing capillary is bonded to the optical waveguide element through an adhesive agent, and a first stain-preventing groove is formed on a portion of the bottom surface of the reinforcing capillary and close to the connection surface of the reinforcing capillary to thereby receive an

excessive portion of the adhesive agent applied between the connection surfaces of the reinforcing capillary and the optical waveguide element and to present staining of the periphery of the reinforcing capillary through which the radiation mode light is outputted.

11. The optical waveguide modulator equipped with an output light monitor as claimed in claim 4, wherein the optical fiber for the output light is bonded to the hole or groove of the reinforcing capillary through an adhesive agent, and

a second stain-preventing groove is formed on a portion of the bottom surface of the reinforcing capillary and close to the light reflecting terminal surface of the reinforcing capillary, to thereby receive an excessive portion of the adhesive agent applied between the optical fiber and the hole or groove of the reinforcing capillary and to prevent staining of the periphery of the reinforcing capillary through which the radiation mode light is outputted.

12. The optical waveguide modulator equipped with an output light monitor as claimed in claim 2, wherein the terminal surface of the reinforcing capillary formed from the light-transmittable material is provided with a surface portion, in which the monitoring light is reflected, and a non-monitoring surface portion, whereby when the radiation mode light radiated from the optical waveguide connection portion of the optical waveguide element through both side portions of the output light-outputting optical waveguide portion passes through the dielectric substrate of the optical waveguide element and the reinforcing capillary connected to the output end surface of the dielectric substrate, only a portion of the radiation mode light radiated to one side portion of the output light-outputting optical waveguide portion is reflected on the monitoring light-reflecting surface portion of the reinforcing capillary toward the monitoring light-receiving means and received as a

monitoring output light by the monitoring light-receiving means, and another portion of the radiation mode light which reaches the non-monitoring surface portion is not received, as a monitoring light, by the monitoring light-receiving means.

13. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein the reinforcing capillary is in the form of a cylinder.

14. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein the terminal reflecting surface portion of the reinforcing capillary intersects the direction of the longitudinal axis of the hole or groove in which the output light-outputting optical fiber is received, at an oblique angle, to thereby enable the radiation mode light reflected on the terminal reflecting surface portion to be received, as monitoring light, by the monitoring light-receiving means.

15. The optical waveguide modulator equipped with an output light monitor as claimed in claim 13, wherein the portion of the radiation mode light reflected on the reflecting surface portion of the cylindrical reinforcing capillary is outputted, as monitoring light, through the periphery of the cylindrical reinforcing capillary, and converged by the lens effect of the periphery of the cylindrical reinforcing capillary, and the converged monitoring light is received by the monitoring light-receiving means.

16. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein a light-reflective membrane is formed on the terminal light-reflecting surface portion of the reinforcing capillary.

17. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein a portion of the terminal surface of the reinforcing capillary is formed into a curved surface projecting

outward, to thereby enable the monitoring light transmitted through the reinforcing capillary to be reflected on the curved surface portion of the terminal surface and converged, and to be received by the monitoring light-receiving means.

18. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12 wherein, in the terminal surface of the reinforcing capillary, a boundary line between the light-reflecting surface portion and the non-monitoring surface portion is located between a transmitting path of a portion of the radiation mode light which reaches the light-reflecting surface portion and another transmitting path of another portion of the radiation mode light which reaches the non-monitoring surface portion; and the boundary line is positioned between a center line of the terminal surface of the reinforcing capillary intersecting the longitudinal axis of the hole and extending in the same direction as that of the boundary line, and a tangential line extending in parallel to the center line and coming into contact with a portion of a periphery line of the hole of the reinforcing capillary from which portion of the periphery line, the light-reflecting surface portion is formed.

19. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein the non-monitoring surface portion of the terminal surface of the reinforcing capillary is one formed in a manner such that a portion of the reinforcing capillary is cut off inward from the terminal surface of the capillary, while another portion of the reinforcing capillary having the light-reflecting surface portion of the terminal surface thereof is not cut off.

20. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12, wherein the non-monitoring surface portion of the terminal surface of the reinforcing capillary is a non-light

reflecting surface not capable of reflecting the radiation mode light.

21. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12 wherein, with respect to the non-monitoring surface portion of the terminal surface of the reinforcing capillary, a means for intercepting the radiation mode light reflected on the non-monitoring surface portion is arranged between the non-monitoring surface portion and the monitoring light-receiving means.

22. The optical waveguide modulator equipped with an output light monitor as claimed in claim 12 wherein, with respect to the non-monitoring surface portion of the terminal surface of the reinforcing capillary, a means for intercepting the radiation mode light is provided in the reinforcing capillary and upstream of the non-monitoring surface portion.

23. The optical waveguide modulator equipped with an output light monitor as claimed in claim 1, wherein the optical waveguide of the optical waveguide element has a monitoring light-outputting optical waveguide portion connected to the waveguide-connecting portion, in addition to the output light-outputting optical waveguide portion, to thereby output the monitoring light through the output end of the monitoring light-outputting optical waveguide portion.

24. The optical waveguide modulator equipped with an output light monitor as claimed in claim 23, wherein an end face of an optical fiber piece for outputting the monitoring light is connected to the outputting end of the monitoring light-outputting waveguide portion;

the optical fiber piece for outputting the monitoring light is held in a groove for the monitoring light, which groove is formed in the reinforcing capillary and is longer than the optical fiber piece for outputting the monitoring light; an end face of the groove for the monitoring light, facing the output end

face of the optical fiber piece for outputting the monitoring light constitutes a reflecting surface for the monitoring light, whereby the monitoring light outputted through the output end of optical fiber piece for outputting the monitoring light is reflected on the above-mentioned reflecting surface, and the reflected monitoring light is received, as an outputted monitoring light, by the monitoring light-receiving means.

25. The optical waveguide modulator equipped with an output light monitor as claimed in claim 24, wherein the reflecting end face of the groove for the monitoring light is constituted by a light-reflecting membrane.

26. The optical waveguide modulator equipped with an output light monitor as claimed in claim 24, wherein the optical fiber piece for the output monitoring light is formed from a multi-mode optical fiber.

27. The optical waveguide modulator equipped with an output light monitor as claimed in claim 24, wherein an X-coupler or a directional coupler is arranged in the waveguide-connecting portion of the optical waveguide element, and the output light-outputting optical waveguide portion and the monitoring light-outputting optical waveguide portion are connected to the X-coupler or the directional coupler.

28. The optical waveguide modulator equipped with an output light monitor as claimed in claim 27, wherein the output light-outputting optical waveguide portion of the optical waveguide element is connected to the waveguide-connecting portion, and the monitoring light-outputting optical waveguide portion is connected to the output light-outputting optical waveguide portion through the directional coupler.

29. The optical waveguide modulator equipped with an output light monitor as claimed in claim 23, wherein an end face of the monitoring light-outputting optical fiber piece is connected to an output end of the monitoring light-outputting optical waveguide portion;

the monitoring light-outputting optical fiber piece is held in a hole or groove formed in the reinforcing capillary and is not longer than the monitoring light-outputting optical fiber;

the hole or groove for the monitoring light formed in the reinforcing capillary inclines in a manner such that the farther the hole or groove for the monitoring light from the connection surface between the reinforcing capillary and the optical waveguide element, the farther the hole or groove for the monitoring light from the hole or groove for the output light; and

the output end face of the monitoring light-outputting optical fiber piece is directed to the monitoring light-receiving means, whereby the monitoring light outputted from the output end face of the monitoring light-outputting optical fiber piece is received by the monitoring light-receiving means.

30. The optical waveguide modulator equipped with an output light monitor as claimed in claim 29, wherein the monitoring light-outputting optical fiber piece is formed from a multi-mode optical fiber.

31. The optical waveguide modulator equipped with an output light monitor as claimed in claim 29, wherein an X-coupler or a directional coupler is arranged in the waveguide-connecting portion of the optical waveguide element, and the output light-outputting optical waveguide portion and the monitoring light-outputting optical waveguide portion are connected to the X-coupler or the directional coupler.

32. The optical waveguide modulator equipped with an output light monitor as claimed in claim 31, wherein the output light-outputting optical waveguide portion of the optical waveguide element is connected to the waveguide-connecting portion, and the monitoring light-outputting optical waveguide portion is connected to the output light-outputting optical waveguide portion through the directional coupler.

33. The optical waveguide modulator equipped with an output light monitor as claimed in claim 23, wherein the monitoring light-outputting optical waveguide portion of the optical waveguide element is connected, together with the output light-outputting optical waveguide portion, to the waveguide-connection portion connected to the plurality of surface waveguide portions, through a directional coupler, a cross-coupler structure or a TAP coupler structure;

the output end of the output light-outputting optical waveguide portion is connected to an input end of an optical fiber inserted into the hole or groove of the reinforcing capillary;

the reinforcing capillary is formed from a light-transmitting material, to thereby enable the monitoring light outputted from the output end of the monitoring light outputting waveguide portion to transmit and permeate through the reinforcing capillary, to be reflected on the light-reflecting surface portion provided in the reinforcing capillary, and to be received by the monitoring light-receiving means; and

the output end of the output light-outputting optical waveguide portion and the output end of the monitoring light-outputting optical waveguide portion are spaced from each other at a distance, the spacing distance being sufficiently large not to cause the monitoring light outputted from the monitoring light-outputting optical waveguide portion and passing through the reinforcing capillary to be affected by the output light outputted from the output end of the output light-outputting optical waveguide portion.

34. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein the terminal surface of the reinforcing capillary is provided with a light-reflecting surface portion which intersects an optical axis of the monitoring light-outputting optical waveguide portion at an oblique angle,

to thereby enable the monitoring light outputted from the output end of the monitoring light-outputting optical waveguide portion and transmitted through the reinforcing capillary to be reflected on the light-reflecting surface portion toward the monitoring light-receiving means.

35. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein the terminal surface of the reinforcing capillary is provided with a curved surface portion projecting outward, to thereby enable the monitoring light transmitted through the reinforcing capillary to be reflected and converged on the curved surface portion and to be received by the monitoring light-receiving means.

36. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein at least a region of the portion of the terminal surface of the reinforcing capillary, which portion does not contribute to transmitting and outputting the monitoring light directed to the monitoring light-receiving means, is cut off.

37. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein the light-reflecting surface portion of the terminal surface of the reinforcing capillary intersects the longitudinal axis of the hole for containing therein the output light-outputting optical fiber at an oblique angle, to thereby enable the radiation mode light reflected on the light reflecting surface portion to be received, as monitoring light, by the monitoring light-receiving means.

38. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein the reinforcing capillary is in the form of a cylinder.

39. The optical waveguide modulator equipped with an output light monitor as claimed in claim 38, wherein the light-reflecting surface of the cylindrical reinforcing capillary enables the radiation mode light

reflected on the light-reflecting surface to pass through the cylindrical reinforcing capillary and to be outputted, as monitoring light, through the peripheral surface of the cylindrical reinforcing capillary, while the monitoring light is converged by the lens effect of the periphery of the cylindrical reinforcing capillary, and the converged monitoring light is received by the monitoring light-receiving means.

40. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein, in the terminal surface of the reinforcing capillary, a boundary line between the light-reflecting surface portion and the non-monitoring surface portion is located between a transmitting path of a portion of the radiation mode light moving to the light-reflecting surface portion and another transmitting path of another portion of the radiation mode light moving to the non-monitoring surface portion, and the boundary line is positioned between a center line of the terminal surface of the reinforcing capillary intersecting the longitudinal axis of the hole and extending in the same direction as that of the boundary line, and a tangential line extending in parallel to the center line and coming into contact with a portion of a periphery line of the hole of the reinforcing capillary from which portion of the periphery line, the light-reflecting surface portion is formed.

41. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein the non-monitoring surface portion of the terminal surface of the reinforcing capillary is one formed in such a manner that a portion of the reinforcing capillary is cut off inward from the terminal surface of the capillary, while another portion of the reinforcing capillary having the light-reflecting surface portion of the terminal surface thereof is not cut off.

42. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein

the non-monitoring surface portion of the terminal surface of the reinforcing capillary is a non-light reflecting surface not capable of reflecting the radiation mode light.

43. The optical waveguide modulator equipped with an output light monitor as claimed in claim 33, wherein with respect to the non-monitoring surface portion of the terminal surface of the reinforcing capillary, a means for intercepting the radiation mode light reflected on the non-monitoring surface portion is arranged between the non-monitoring surface portion and the monitoring light-receiving means.

44. The optical waveguide modulator equipped with an output light monitor as claimed in any one of claims 1 to 43, wherein the optical waveguide element has a SiO_2 layer formed on a portion of the optical waveguide other than an input end portion of the surface optical waveguide portion and the output end portions of the output light-outputting optical waveguide portion and the monitoring light-outputting optical waveguide portion.